# 3. Cost and Emission Reduction Analysis of $SF_6$ Emissions from Electric Power Transmission and Distribution Systems in the United States

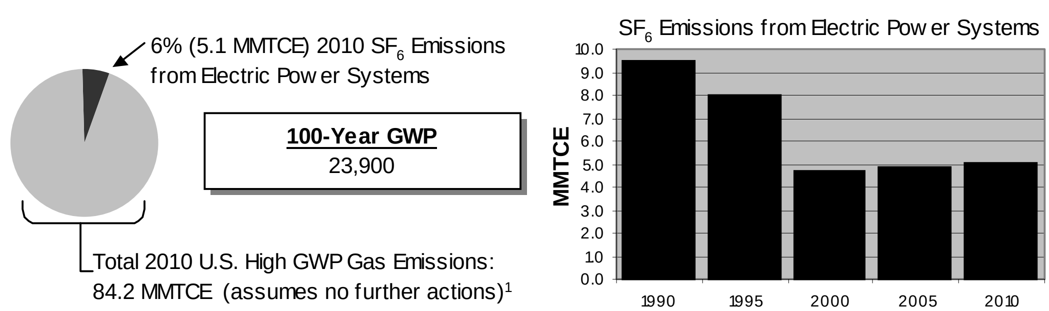
## 3.1 Introduction

Sulfur hexafluoride ($SF_6$) is a colorless, odorless, non-toxic, and non-flammable gas used as an insulator in electric transmission and distribution equipment. $SF_6$ has a 100-year GWP that is 23,900 times that of carbon dioxide and has an atmospheric lifetime of 3,200 years (EPA, 2000). By 2010, under a business-as-usual scenario, the United States would be expected to emit 5.1 MMTCE of $SF_6$ (see Exhibit 3.1).[1] However, as noted below, actual emissions in the future are expected to be lower as a result of voluntary industry actions.

$SF_6$ is a manufactured gas primarily used as an electrical insulator in equipment that transmits and distributes electricity. Leaks from this equipment and venting of the gas during equipment servicing and disposal of equipment are the main sources of emissions. Worldwide, an estimated 80 percent of $SF_6$ use is in electrical transmission and distribution systems. The gas has been employed by the electric power industry in the United States since the 1950s because of its dielectric strength and arc-quenching characteristics. $SF_6$ replaced flammable insulating oils in many electricity transmission applications and allows for the employment of more compact electrical equipment in dense urban areas.

Gas-insulated circuit breakers are the largest source of fugitive $SF_6$ emissions in U.S. electricity systems. In addition, there are somewhat less than 100 gas-insulated substations (GIS) that constitute a smaller source of $SF_6$ emissions. In general, older equipment produces more fugitive emissions than newer equipment. $SF_6$ can also be released when equipment is opened for routine servicing. For example, the

**Exhibit 3.1: $SF_6$ Emissions from Electric Power Transmission and Distribution Systems**




[1] An explanation of the business-as-usual scenario under which baseline emissions are estimated appears in the Introduction to the Report.

older dual-pressure breakers, which need servicing every six years or so, are a strong source of fugitive emissions. The newer equipment is rarely opened for routine servicing because the internal components last a longer time (10-12 years). Sometimes, $SF_6$ is vented to the atmosphere during servicing, but increased environmental awareness and large increases in the cost of $SF_6$ during the mid-1990's have significantly reduced this practice.

The $SF_6$ Emission Reduction Partnership for Electric Power Systems began in early 1999. This partnership is one of the newest voluntary initiatives sponsored by EPA under the CCAP. The Partnership is a collaborative effort between EPA and the electric power industry to identify technically and economically feasible actions that reduce $SF_6$ emissions. Industry partners submitted their first annual reports in mid-2000.

## 3.2 $SF_6$ Baseline Emission Estimates

Exhibit 3.2 presents estimated historical $SF_6$ emissions from U.S. electric power systems. Emission estimates are based on annual reports for 1999 received via the $SF_6$ Emission Reduction Partnership for Electric Power Systems. Although the partner utilities only represent a subset of the U.S. utility population, regression analysis demonstrates that a statistically significant relationship exists between reported emissions and the size of their respective transmission systems (measured in miles). This relationship was used to calculate emissions on the national level for 1999. Since partner reports were not available for other years, the 1990 through 1998 historical emissions were scaled according to world sales of $SF_6$ to utilities (Smythe, 2000). Emissions were forecasted for 2000 to 2010 by assuming that $SF_6$ use would grow at a rate of 0.7 percent per year, based upon growth in electricity consumption and a smaller but offsetting decline in average equipment charge size.

Exhibit 3.3 presents future baseline emission estimates. Future emission estimates do not include reductions that might occur under CCAP.

**Exhibit 3.2: Historical $SF_6$ Emissions from Electric Power Systems (1990-1999)**

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Emissions (MMTCE)** | 9.5 | 9.9 | 9.2 | 10.4 | 9.5 | 8.0 | 8.1 | 7.4 | 6.1 | 4.7 |
| **Emissions (metric tons $SF_6$)** | 1,455 | 1,513 | 1,405 | 1,588 | 1,464 | 1,234 | 1,247 | 1,141 | 939 | 723 |

Source: EPA estimates.
Note: Conversion to MMTCE is based on a GWP of 23,900.

**Exhibit 3.3: Baseline $SF_6$ Emissions from Electric Power Systems (2000-2010)**

| | 2000 | 2005 | 2010 |
|---|---|---|---|
| **Emissions (MMTCE)** | 4.7 | 4.9 | 5.1 |
| **Emissions (metric tons $SF_6$)** | 723 | 748 | 775 |

Notes:
Forecast emissions are based on a business-as-usual scenario, assuming no further action.
Conversion to MMTCE is based on a GWP of 23,900.

## 3.3 $SF_6$ Emission Reduction Opportunities

The most promising options to reduce $SF_6$ emissions can be grouped into four categories: recycling, leak detection and repair, equipment replacement, and use of advanced leak detection technologies. Each is summarized below.

### *Use of Recycling Equipment*

Recycling equipment allows $SF_6$ to be captured and recycled rather than vented to the atmosphere during equipment maintenance and retirement. EPA conservatively estimates that $SF_6$ recycling can eliminate 10 percent of total $SF_6$ emissions from U.S. electric power systems.

### *Leak Detection and Repair*

Many U.S. utilities already implement cost-effective leak detection and repair. Normal procedures require taking units out of service to search for $SF_6$ leaks. If thoroughly implemented in the United States, EPA estimates that leak detection and repair could reduce $SF_6$ emissions from this sector by about 20 percent.

### *Equipment Replacement/Accelerated Capital Turnover*

The owners and operators of electric utilities often keep old systems in operation because the systems tend to be reliable. However, reliability can be improved cost-effectively by replacing equipment to reduce greenhouse gas emissions, as experienced in the natural gas and refrigeration industries. Since much of the $SF_6$ emitted from electric power transmission and distribution systems comes from older equipment, which tends to use larger amounts of $SF_6$ and have higher leak rates than newer equipment, replacing the older capital stock would reduce $SF_6$ emissions and improve overall efficiency. Perhaps 50 percent or more of all emissions from older equipment could be avoided if all older equipment were replaced. However, the uncertainty created by the rapidly evolving electricity market has made utilities reluctant to invest in the replacement of older breakers with new, “tighter” units (Bolin, 1998).

### *Advanced Leak Detection Technologies*

A laser leak detection system is capable of finding leaks with a high degree of accuracy without any modifications or physical connections to circuit breakers. The advantages over traditional leak detection procedures are the ability to perform leak detection without having to take equipment out of service and the dramatic reduction in time necessary to detect a leak. The GasVue laser camera, a laser leak detection system developed with the support of the Electric Power Research Institute (EPRI) by Laser Imaging Systems of Punta Gorda, Florida, has been successfully used at a wide range of utilities in the United States and abroad (Moore, 1999).

## 3.4 Cost Analysis

The most promising options to reduce $SF_6$ emissions from electric power systems are $SF_6$ recycling and $SF_6$ leak detection and repair. $SF_6$ recycling could reduce emissions by about 10 percent and is currently cost-effective. Leak detection and repair could reduce emissions cost-effectively by 20 percent. All cost analyses were based on a four percent discount rate (Exhibit 3.4), a ten-year project lifetime, and an $SF_6$ price of \$8.00 per pound. For sensitivity comparisons the cost analysis is also provided at an eight percent discount rate. The financial assumptions and results specific to each emission reduction option are presented below.

### *Recycling Equipment*

The capital costs of recycling equipment range from around $5,000 to over $100,000 per utility. For this analysis, typical recycling expenditures have been set at $25,500 per utility. However, this capital investment produces O & M savings of nearly $1,600 per year per utility due to reduced purchases of $SF_6$. In 2010 this option could reduce emissions by 0.5 MMTCE or ten percent of baseline emissions at a savings of $2.30 per metric ton of carbon equivalent (TCE).

### *Leak Detection and Repair*

There are no capital costs associated with leak detection and repair and O&M costs are estimated to be $2,190 per utility due to the increased labor costs associated with this option. This option could reduce emissions by 1.0 MMTCE in 2010, 20 percent of baseline emissions, at a cost of $1.62 per TCE.

### *Equipment Replacement/Accelerated Capital Turnover*

The capital costs of this option vary by equipment type. Circuit breakers (below 34.5 kV) may be replaced with vacuum breakers. The replacement cost varies from $25,000 to $75,000 per unit. Medium and high voltage breakers are expected to continue to use $SF_6$ because no other option is currently available. Older breakers are assumed to leak more and are being replaced by new equipment (as part of routine turnover) at a cost of approximately $200,000 to $750,000 per unit. Additional research into the existing equipment stock and potential for replacement will be necessary to develop cost estimates for emission reductions.

### *Advanced Leak Detection Technologies*

The capital cost per GasVue leak detection camera is approximately $100,000. Additional research into the potential emission reductions from this option will be necessary to develop estimates for O&M costs and the total cost of emission reductions.

**Exhibit 3.4: Emission Reductions and Cost 2010 (at 4% and 8% discount rate)**

| Option | Break-even Cost ($/TCE) Discount Rate | | Incremental Reductions | | Sum of Reductions | |
|---|---|---|---|---|---|---|
| | 4% | 8% | MMTCE | Percent | MMTCE | Percent |
| Leak Detection | 1.62 | 1.62 | 1.0 | 20% | 1.0 | 20% |
| Recycling Equipment | 2.30 | 3.28 | 0.5 | 10% | 1.5 | 30% |

Notes:
Values in parenthesis indicate savings.
2010 baseline $SF_6$ emissions from electric utilities equal 775 metric tons $SF_6$ or 5.1 MMTCE.
This table is based on the GWPs listed in the Introduction to the report.

## 3.5 References


Bolin, P.C. 1998. IEEE Power Engineering Society, Subcommittee.

Moore, T. 1999. *Seeing $SF_6$ in a New Light*. EPRI Journal. Summer 1999. Palo Alto, California.

Smythe, Katie D. 2000. "Production and Distribution of $SF_6$ by End-Use Application." Presented at the *Conference on $SF_6$ and the Environment: Emission Reduction Strategies*, November 2-3, 2000, San Diego, California. (Available online at http://www.epa.gov/highgwp1/sf6/pdf/smythep.pdf).